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EVALUATE FUNDAMENTAL APPROACHES TO LONGWALL DUST CONTROL SUBPROGRAM F - REVERSED DRUM ROTATION

Contract J0318097

Foster-Miller, Inc.

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7. Author(s)
J. Ludlow, J. Kelly, S. Ruggieri

8. Performing Organization Rept. No.
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9. Performing Organization Name and Address
Foster-Miller, Inc.
350 Second Avenue
Waltham, MA 02254

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In longwall mining, a significant portion of the shearer operator's dust exposure is caused by dust generated during loading. With the conventional direction of shearer drum rotation, loading efficiency is usually poor due to obstructions caused by the ranging arms and the cowl support arms. By reversing the normal direction of rotation, however, the arms no longer provide an obstruction. This results in improved loading efficiency and reduced dust generation.

This report describes the reversed drum rotation concept and presents the results of a field survey and underground evaluation conducted to prove its feasibility and to measure its dust control benefits. Through this effort, the technique was shown to be feasible from both a mining and mechanical standpoint. During the underground test, it reduced dust levels near the shearer operator's positions by about 85%.

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FOREWORD

This report was prepared by Foster-Miller, Inc., Waltham, MA, under United States Bureau of Mines Contract No. J0318097. This contract was initiated under the Health and Safety Technology Program. It was administered under the technical direction of the Pittsburgh Research Center with Mr. Robert Jankowski acting as Technical Project Officer. Mr. Louis Summers was the Contract Officer for the Bureau. This report summarizes the work completed on Subprogram F of the contract during the period September 1982 to June 1984. This report was submitted by the authors in February 1990.

The technical effort was performed by the Mining Division of the Engineering Systems Group under the direction of Mr. Terry L. Muldoon, with Mr. Steven K. Ruggieri as Program Manager and Mr. Jonathan Ludlow as Subprogram F Principal Investigator.

The authors would like to extend their special appreciation and acknowledgment to the numerous mining industry representatives who provided valuable input to the program and who provided valuable assistance during the underground evaluations. The assistance, guidance, and cooperation extended by Dr. Frederick Kissell and his staff are especially appreciated.

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EXECUTIVE SUMMARY

In longwall mining, a significant portion of the shearer operator's dust exposure is caused by dust generated and liberated during the loading process. The amount of dust generated is a function of loading efficiency, which is highly dependent on the extent of obstruction caused by the ranging arms and cowl support arms.

By reversing the normal rotational direction of shearer drums, the obstruction to loading caused by the arms is minimized. This results in more efficient loading, which in turn reduces the amount of dust generated.

The objective of this subprogram was to further investigate the potential benefits of reversed drum rotation and to evaluate the concept through an underground field trial. The following paragraphs describe the basic concepts of the technique and summarize the results of the underground evaluation.

CONCEPTS OF REVERSED DRUM ROTATION

In a conventional drum layout, coal is cut by descending picks on the leading drum and by ascending picks on the trailing drum as shown in figure 1(a). For both the leading and trailing drums, the loading of coal takes place near the obstructions caused by the ranging arms and cowl support arms. Since this prevents coal from leaving the helices of the drums efficiently, the coal is often crushed and ground in the process. In the case of the trailing drum, coal is sometimes projected into the airstream over the ranging arms.

In a reversed drum layout, coal is cut by ascending picks on the leading drum and by descending picks on the trailing drum as shown in figure 1(b). In the case of the leading drum, the loading path is considerably shorter and the coal leaves the drum helix well away from the obstructions of the ranging and cowl arms. The length of the loading path for the trailing drum is similar to the conventional arrangement; however, the coal is pushed in the opposite direction, away from the ranging and cowl arms. This reduces the tendency to toss coal into the airstream.

BACKGROUND DATA SEARCH

A background data search was conducted by visiting a mine already using reversed drum rotation. The purpose

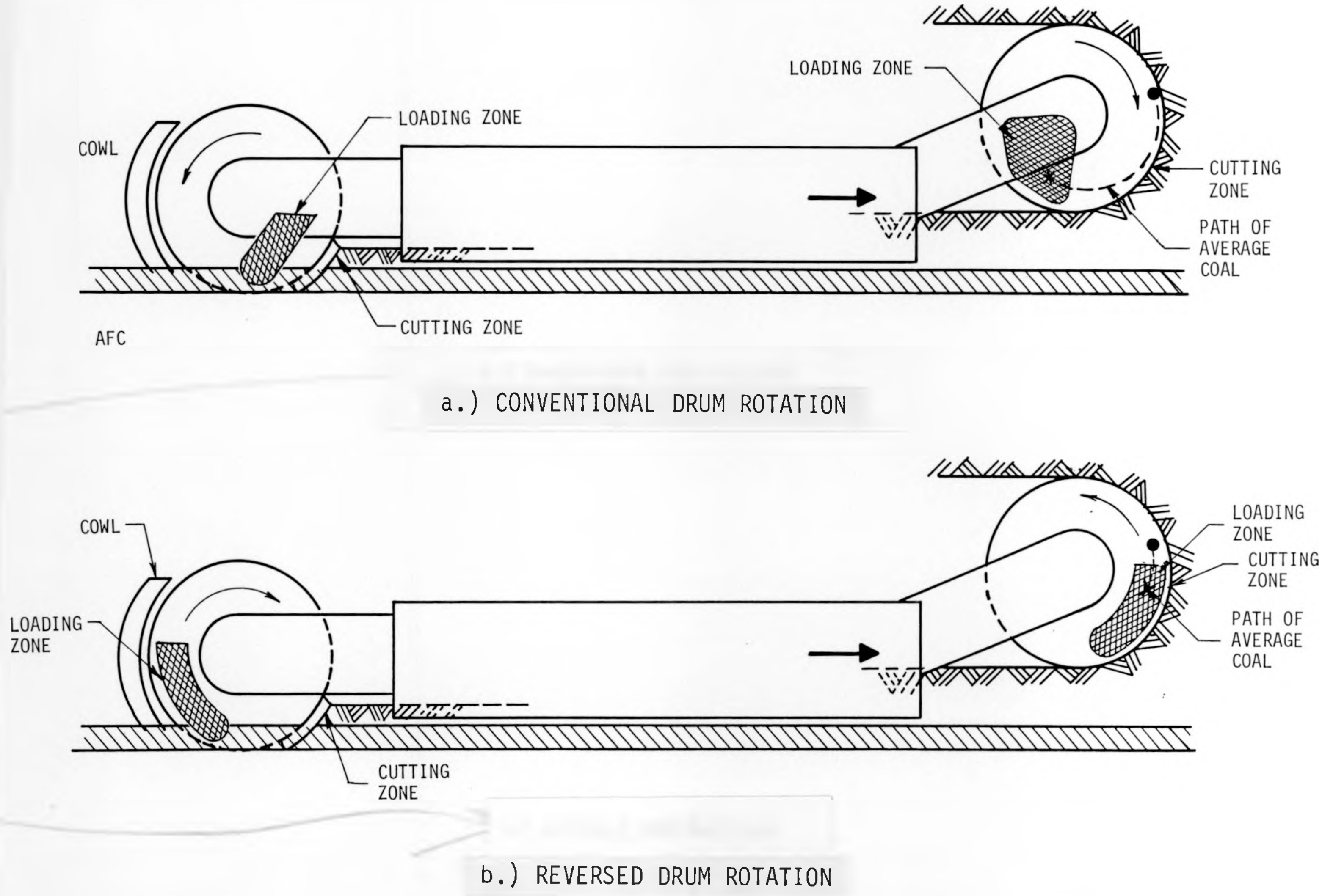

FIGURE 1. - Reversed drum rotation improves coal loading efficiency.

was to prove the feasibility of the concept and to document its benefits in preparation for the full underground evaluation of the technique. Of three mining operations which were identified as having tried reversed drum rotation, only United States Steel's Morton Mine was still using the technique at the time (the other two had been withdrawn due to a depressed demand for coal). Morton was using a single drum machine on the headgate end of the shearer cutting the full 48-in. seam height bidirectionally.

Low levels of face activity during the brief survey precluded the collection of adequate dust data for analysis. However, visual observations supported the perceived benefits of reversed drum rotation. During cutting in both directions, coal was quickly and efficiently loaded onto the conveyor without interference by the shearer body or by the ranging and cowl support arms. Very little coal left the drum from any area other than the loading zone. In addition, the respirable dust which was produced propagated directly from the cutting area.

Overall, the results of the field survey clearly demonstrated the feasibility of reversed drum rotation from both a mining and mechanical standpoint.

UNDERGROUND EVALUATION

The underground evaluation of reversed drum rotation was conducted at Jim Walter's Resources No. 4 Mine near Brookwood, AL. The mine was using reversed drum rotation on a double drum shearer, using a modified half-face cutting cycle; the bulk of coal extraction occurred while cutting with the direction of airflow. Extraction height was 66 in. (60-in. coal plus some floor rock).

The strategy for the evaluation was to monitor dust levels for 1 week using the existing reversed rotation. The drums were then swapped and converted back to conventional rotation for an additional week of dust monitoring. Dust samples were collected at three locations: intake to the shearer, between the operators and downwind of the shearer.

In general, reversed rotation resulted in a significant reduction in respirable dust levels in the vicinity of the shearer operators. Concentrations averaged 5.48 and 0.83 mg/m^3 for conventional and reversed rotation, respectively, between the shearer operators. Nearly all of the 0.83 mg/m^3 measured during reversed rotation was intake dust approaching the shearer from outby; there was little or no evidence of shearer-generated dust impacting the operators during reversed rotation.

No significant difference was noted in dust levels downwind of the shearer when using conventional versus reversed rotation. Similarly, the direction of rotation had little effect on dust levels during tramming back against the direction of airflow.

From an operational standpoint, reversed rotation had both positive and negative effects. On the positive side, the loading characteristics of reversed rotation produced a better size range of run-of-mine (ROM) product. The result was a reduced proportion of fines in the product, which improved the throughput of the preparation plant. Management considered this an important benefit and it provided a primary reason for the decision to use reversed rotation at Jim Walter's Resources (JWR).

On the negative side, reversed rotation proved inefficient in dealing with large rock or coal lumps. During conventional rotation, the picks on the leading drum are descending and will generally trap and cut up lumps. During reversed rotation, however, the picks are ascending and will usually lift the lumps and load them onto the conveyor without breaking them. The consequence (seen to an extent during the evaluation) can be increased blockages at the face conveyor/stageloader transfer point. This can be minimized by the use of a lumpbreaker on the end of the shearer.

1. INTRODUCTION

In 1981 the Bureau awarded Foster-Miller Contract JO31807; "Evaluate Fundamental Approaches to Longwall Dust Control." The overall objective of the contract was to evaluate the effectiveness of available dust control technology for double-drum shearer longwall sections in a coordinated, systematic program at a few longwall test sections and to make the results available to the entire coal mining industry.

This program investigated ten different dust control techniques within nine subprograms. The subprograms included:

a. Subprogram A - Passive Barriers/Spray Air Movers for Dust Control

b. Subprogram B - Practical Aspects of Deep Cutting

c. Subprogram C - Stageloader Dust Control

d. Subprogram D - Longwall Automation Technology

e. Subprogram E - Longwall Application of Ventilation Curtains

f. Subprogram F - Reversed Drum Rotation

g. Subprogram G - Reduction of Shield Generated Dust

h. Subprogram H - Air Canopies for Longwalls

i. Subprogram I - Mining Practices; Division I - Homotropal Ventilation; Division II - Ventilation Parameters.

These nine subprograms encompassed a broad range of dust control techniques ranging from administrative controls to new hardware. They spanned not only presently employed methods but also those recently adopted in the United States and those proposed for the future.

The report constitutes the Final Technical Report for Subprogram F, "Reversed Drum Rotation," summarizing the effort expended and the results obtained.

Companion volumes document the results of the other subprograms.

1.1 BACKGROUND AND PRIOR RESEARCH

There is reason to believe that the shearer operator's dust exposure can be significantly lowered by reducing the amount of dust generated and liberated during the loading process. The technical literature and various experiments suggest that loading conditions will be significantly improved if the direction of drum rotation is reversed. This is because with reversed rotation both drums will experience less obstructed loading. In the case of the leading drum, the time that the coal remains in the drum and the distance travelled by the coal within the drum will also be reduced. Reversed rotation will, therefore, reduce recirculation and coal breakage by allowing unobstructed loading and increasing the capacity of the drum.

Available background information from research comes from a pair of surface loading tests conducted in France and West Germany and a systematic underground study of the effect of operating conditions on machining performance and dust levels conducted as a doctoral research project at Clausthal University.

The loading tests conducted by Scholz[1] and by Guillon and Pechalat[2] were concerned with efficiency of loading and did not, in most cases, include dust measurements. Nevertheless, it is generally assumed that efficient loading, like efficient cutting, is synonymous with dust control.

Scholz showed that floor-to-roof loading increased efficiency both in terms of proportion of product loaded and the power consumed. Figures 2 and 3 summarize some of his findings. Guillon and Pechalat also reported that power requirements were low when loading from floor to roof.

Heiermann[3], working with a single drum shearer in a narrow seam, produced the results shown in figure 4, in which cutting from floor-to-roof produced consistently lower levels of airborne dust. No adequate instrumentation for measurement of respirable fractions was available at the time of this latter investigation.

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[1] Scholz, G., "Loading Action of Shearers: Experiment and Theory," Clausthal Technical University, Doctoral Thesis, 1975, NCB Translation.

[2] Guillon, P., and Pechalat, F., "Etude du Chargement par les Tambours," CHERCHAR Publication No. 22010, 1972.

[3] Heiermann, H., "Studies on Dust Generation and Size Distribution from Shearers through Statistical Methods," Clausthal Technical University, Dissertation, 1967.

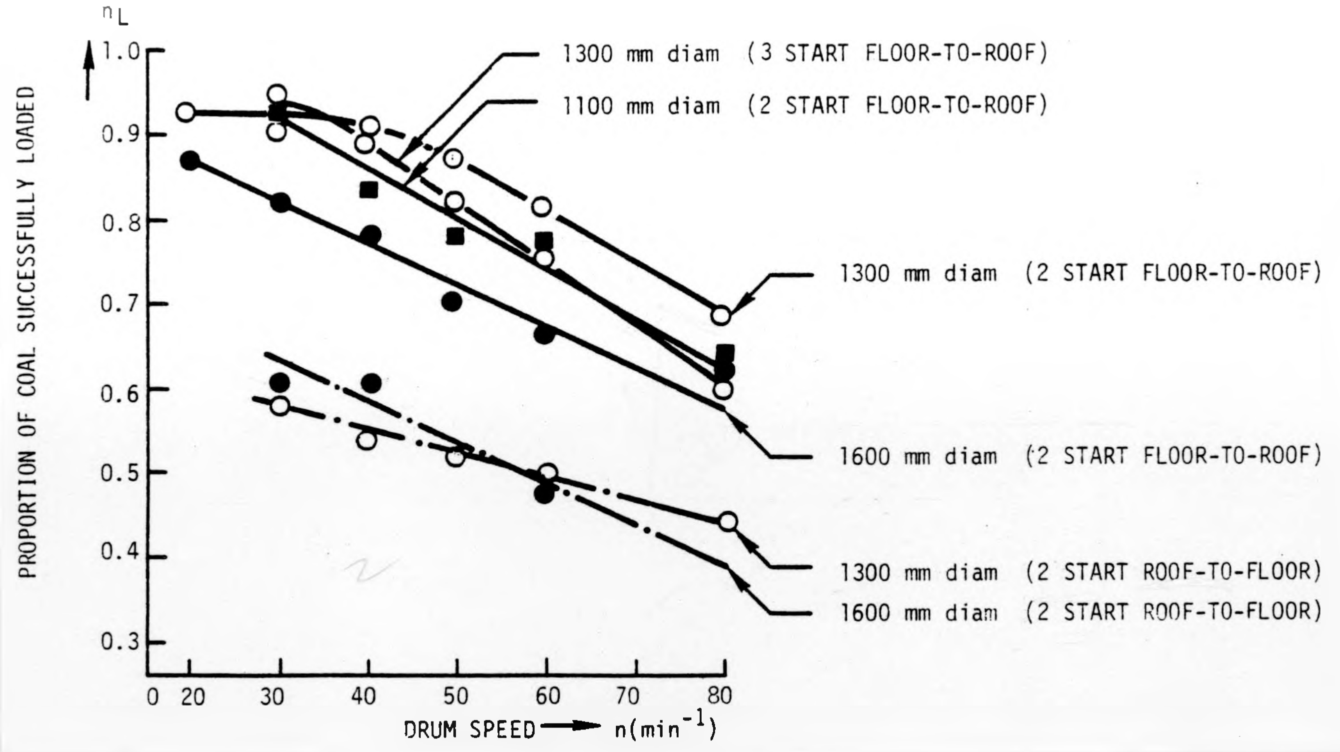


FIGURE 2. - Loading efficiency versus drum speed and direction.

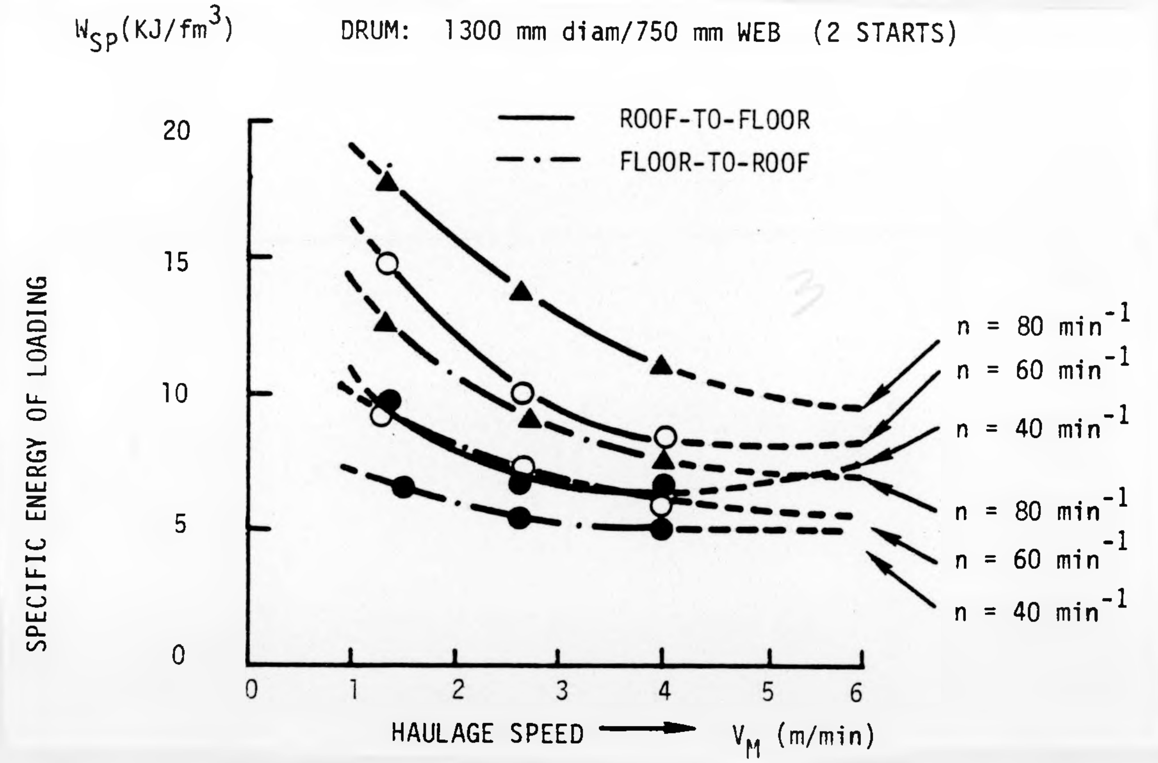


FIGURE 3. - Specific loading energy consumption versus direction of rotation.

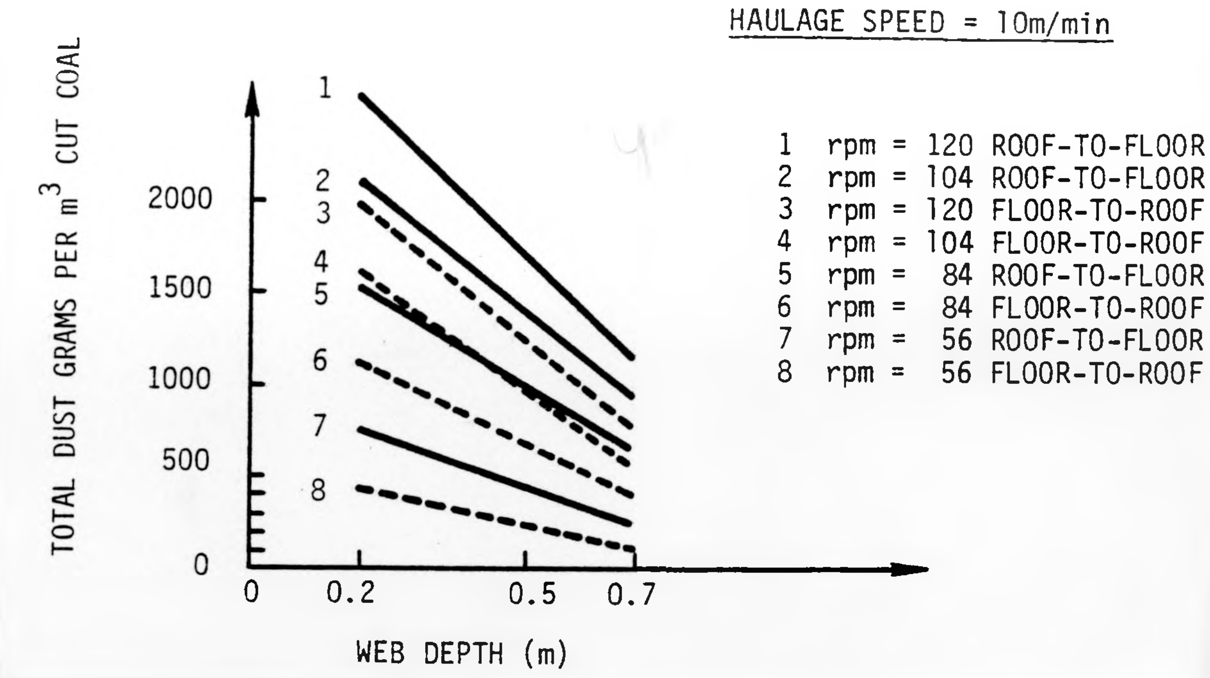


FIGURE 4. - Total dust make is reduced with reversed rotation and increased web depth.

1.2 TECHNICAL DESCRIPTION OF THE CONCEPT

Figure 5 shows the conventional drum layout on a double-ended ranging drum shearer. In this configuration, coal is cut by descending picks on the lead drum (slot-milling) and by ascending picks on the trailing drum (up-milling). If the drums are switched end-to-end on the machine and the direction of drum shaft rotation reversed,the loading action will remain positive while the direction of cutting will be reversed in each case. The consequence of reversed rotation is that coal is no longer required to pass through an obstructed path on its way to the face conveyor.

In the case of the leading drum, the loading path with reversed rotation is through the lower of the two quadrants in which the coal is cut and coal is now required to pass an average distance of only one-eighth of the drum perimeter before leaving the drum. In the case of conventional rotation, the coal must pass through approximately three-eighths of the drum before being loaded in the lower of the two noncutting quadrants. It is this quadrant that is obstructed by the ranging arm and cowl support arm on conventional machines. If coal cannot leave the helix of the drum, it will be, at best, crushed

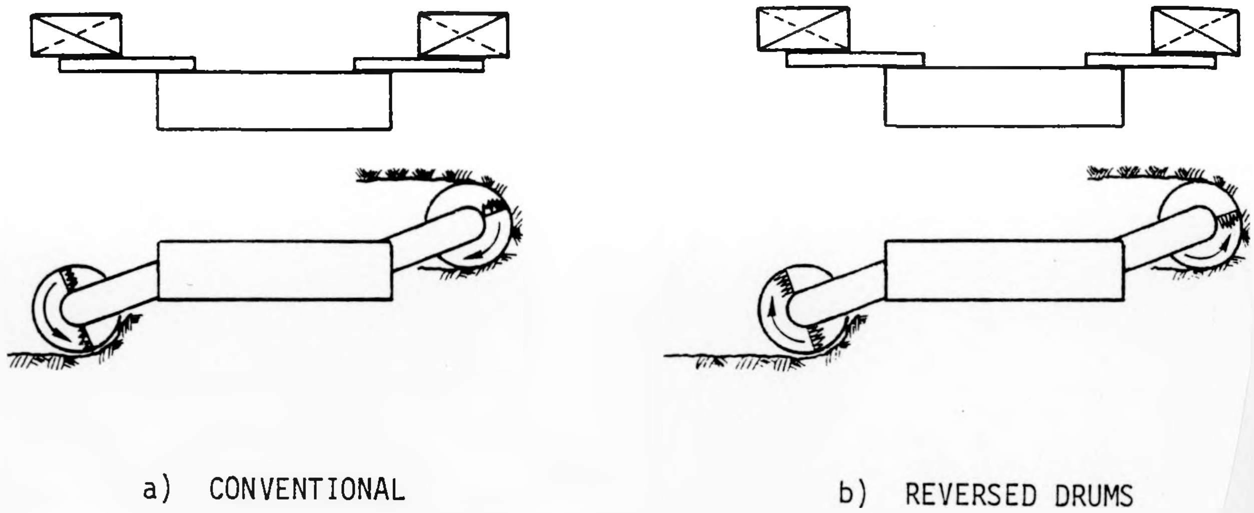


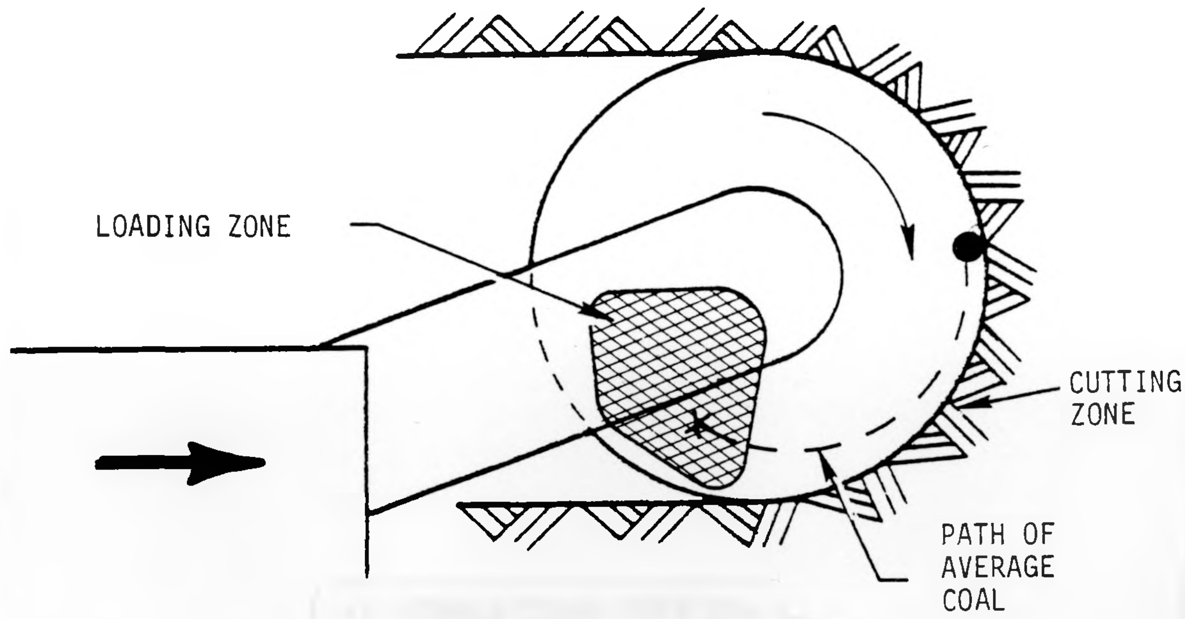
FIGURE 5. - Conventional and reversed rotation strategies.

and ground within the choked drum, and, at worst, projected into the airstream over the ranging arm. Figure 6 shows these two situations graphically.

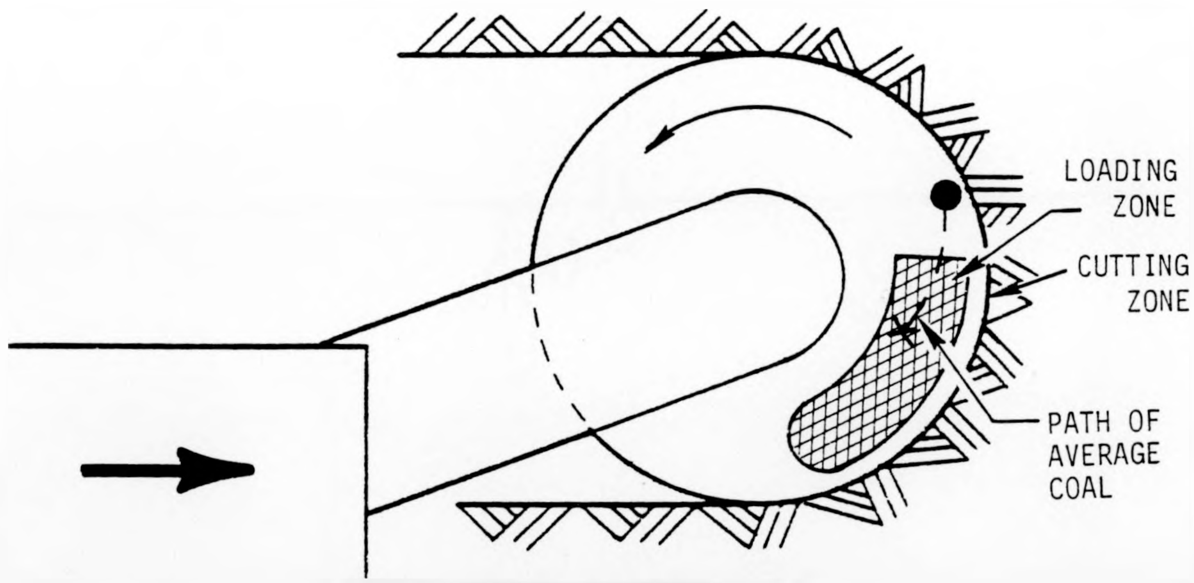
The trailing drum in the conventional regime has the more onerous task of loading coal cut from the lower bench up onto the conveyor. Figure 7(a) shows that although the loading zone and the cutting zone are adjacent, the loading area will be substantially blocked by the ranging arm and the conveyor which, on a high capacity longwall, will be 10 in. in depth.

If the drums are reversed, the loading zone is moved to the trailing portion of the drum and the principal obstructions are removed (see fig. 7(b)). In this manner, the tendency of trailing drums to toss coal into the airstream is reduced.

The creation of improved loading conditions is particularly critical in thin seams, where shearer design is based upon the requirements of cutting and loading coal in a confined space. Because the ranging arm totally obstructs the shearer body side of the drum end, in-web shearers are designed to cut floor-to-roof with their leading drum and generally load successfully where there is no other constraint on their performance.



a) CONVENTIONAL ROTATION



b) REVERSED ROTATION

FIGURE 6. - Reversed rotation improves coal flow around this ranging arm.

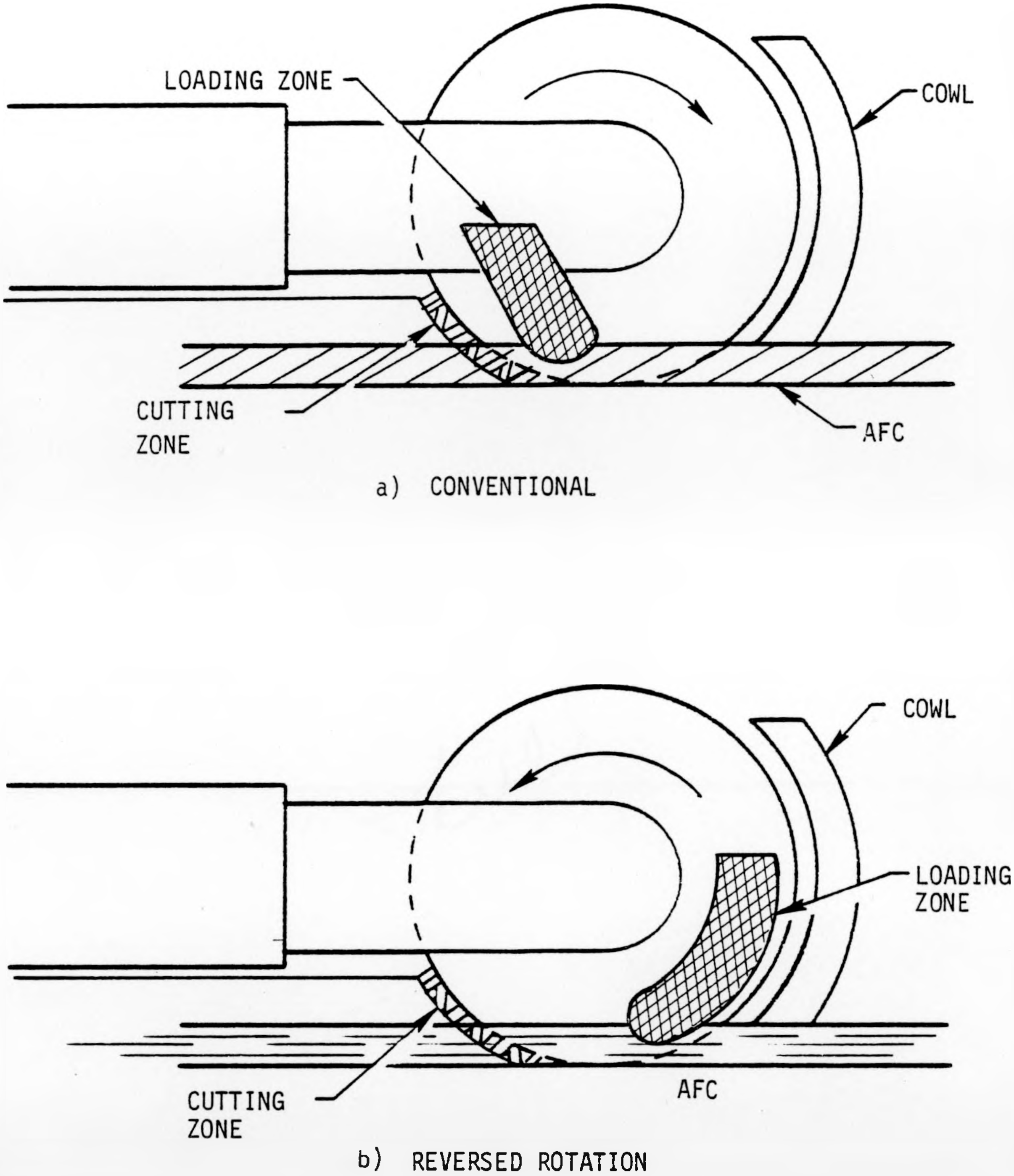


FIGURE 7. - Reversed rotation reduces trailing drum ejection of coal into face airflow.

1.3 SUBPROGRAM OBJECTIVES

The objective of this subprogram was to conduct an underground evaluation of the reversed drum rotation concept and to provide guidance for its application to other longwalls. The major tasks necessary to achieve this goal were:

a. Background data search

b. Mine site selection

c. Underground evaluation.

Details of these tasks are discussed in the following sections.

2. BACKGROUND DATA SEARCH

The objective of the background data search was to visit a mine already using reversed drum rotation to prove its feasibility and document its benefits. This would provide a better understanding of reversed drum principles and operations prior to committing to a full underground evaluation. The following organizations which had known prior experience with reversed drum operations were contacted:

a. Consol/Itman (in-web shearer)

b. United States Steel (Gary district)

c. United States Steel (Morton No. 34).

It was found that both the Itman and Gary shearers had been withdrawn due to depressed demand for coal. Access to the face at United States Steel's Morton Mine (No. 8 South) was gained, however, in conjunction with another subprogram and the machine was observed during portions of two mining cycles.

The Morton installation was a single drum machine with limited ranging capacity. The single drum cut the full 48-in. extraction height and was at the headgate end of the shearer. During cutting from tail to head, the drum cut floor-to-roof and coal was loaded promptly and efficiently from the sector of the drum adjacent to the cutting zone. It was very evident that, if the drum had rotated in the opposite direction (roof-to-floor) the loading area would have been totally obstructed by the shearer body, the short ranging arm and the cowl support arms. Figure 8 indicates the loading zone observed at the Morton installation with reversed rotation. For comparison, the loading zones which would result from conventional rotation are also indicated.

When the machine cut towards the tailgate, the drum again cut a full section. In this case, the coal was loaded from the trailing half of the drum and passed through the split cowl support arms. Again, it was evident that rotation in the conventional direction would have made loading difficult.

Due to a low level of face activity during this study, little data was gathered on dust levels around the shearer. However, discussions with mine management confirmed the impression that levels of dust at the headgate shearer operator's position were usually low, and that there was almost no rollback of dust from the loading

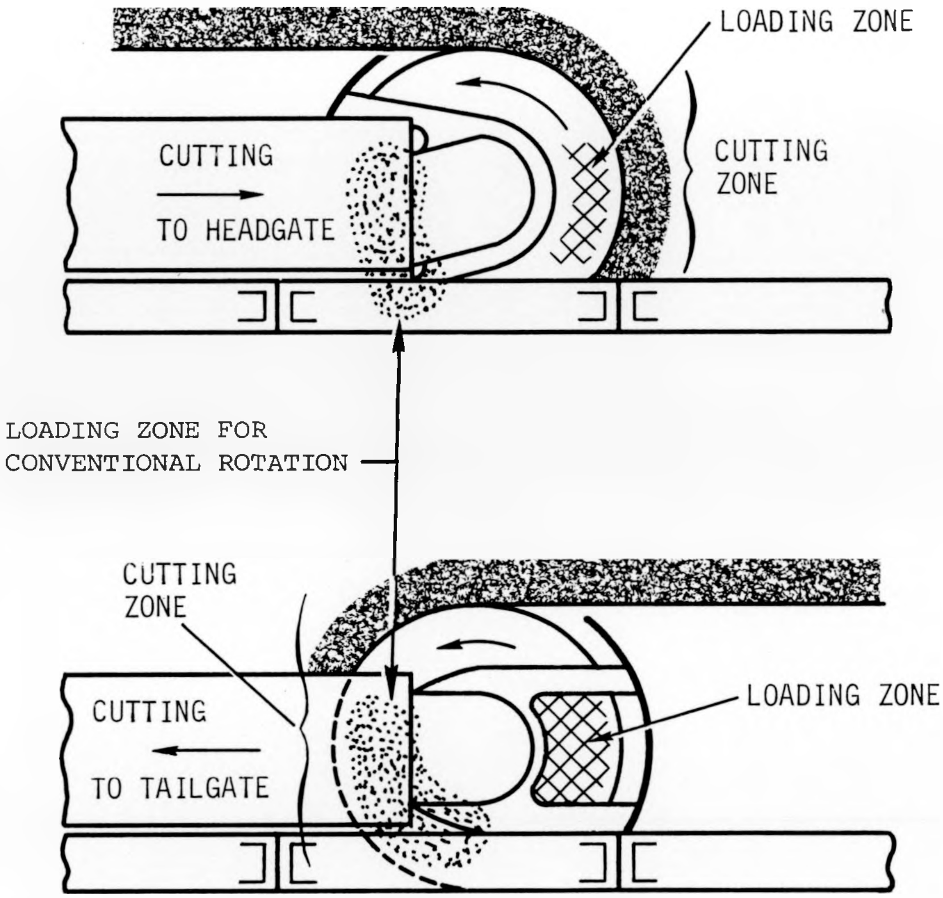


FIGURE 8. Reversed drum rotation at Morton No. 34 mine.

zone. In addition, visual observation during the survey suggested that very little coal was leaving the drum from any area other than the loading zone and that what dust was produced propagated directly from the cutting areas.

These observations could not be quantified since it was impossible to compare the existing reversed rotation against conventional rotation. The Morton Mine did, however, provide an example of an operation where reversed drum rotation was proven feasible from a mining and mechanical standpoint.

A number of measurements were also made at North American Coal Company's Quarto No. 4 Mine to establish the potential benefit of reversed drum rotation. This was done by demonstrating the disproportionate exposure suffered by trailing drum operators during cutting with the ventilation. Measurements at Quarto produced the data shown in table 1 which suggest that, even when the trailing drum operator is well upwind of the drum which is cutting most of the coal, his exposure will either be higher than or comparable to that of the leading drum man. This is believed to be because the small proportion of coal cut by the trailing drum is loaded very inefficiently (with conventional rotation) and produces a disproportionate amount of dust.

TABLE 1. - Comparison of operator's exposure showing disproportionate exposure of upwind (headgate) operator

Longwall	Activity	Exposure at operator's position, [(mg/m^3) x min]	
		Headgate operator	Tailgate operator
2	Cutting to HG	91.3	44.7
2	Cutting to TG	41.8	30.7
1	Cutting to HG	87.5	77.0
1	Cutting to TG	59.8	63.7

3. MINE SITE SELECTION

With the feasibility and potential benefits of reversed drum rotation shown through the field surveys, site selection efforts began for the full underground evaluation of the technique. Discussions were held with the following organizations:

a. Consolidation Coal (headquarters)

b. North American Coal Company (Quarto)

c. Kaiser Steel Mining

d. United States Steel (headquarters)

e. Eastern Associated Coal Company

f. Jim Walter's Resources (JWR).

Ultimately, JWR was chosen as the evaluate site. JWR offered a number of advantages as a mine site. Among these were a machine that at the time operated normally with reversed drum rotation and a management who regarded "floor-to-roof" cutting as a realistic alternative to current practice rather than defiance of convention. As a consequence, an agreement was reached that would allow Foster-Miller to monitor a temporary changeover from reversed to conventional rotation that was scheduled to occur at JWR No. 4 mine. This visit was originally conceived as a small-scale pilot study since the planned change of rotation would also involve a change of drums. Even though both sets of drums were built to the same specification, this would introduce additional uncertainty into any results obtained.

Following further discussions, JWR agreed to change direction with the existing set of drums, thus allowing an evaluation in which the effect of drum direction would not be confused with that of changing to new drums. An informal agreement was reached which would allow Foster-Miller access to the longwall for a period sufficient to conduct the evaluation.

4. UNDERGROUND EVALUATION

4.1 EVALUATION SITE DESCRIPTION

The site selected for the evaluation at JWR was the No. 2 longwall at JWR No. 4 mine near Brookwood, AL. This longwall operates in the Warrior basin at a depth of approximately 2,000 ft. The vital statistics of the longwall are given in table 2. The salient features that affect the evaluation are summarized in the paragraphs below:

a. Ventilation - This face is ventilated in the homotropal (tail-to-head) direction. This fact, taken by itself, has little effect on the reversed drum evaluation, except that it results in intake dust levels that are lower than they might otherwise have been. The ventilation quantity, however, was high, with a nominal 50,000 cfm passing onto the face. This results in a face velocity over the panline in the region of 800 to 1,000 ft/min.

b. Mining cycle - The mining cycle used is a variation of the conventional modified half-face method. The modification involved the inversion of the cycle so that the bulk of cutting is done from tailgate-to-headgate (with ventilation and coal flow). Some supports are pulled behind the shearer on the tail-to-head (cutting) pan. The remainder are advanced during the flit from head to tail.

c. Extraction height and seam condition - The longwall operates at a nominal extraction height of 66 in. At this height, the main seam (of just under 60 in.) is extracted fully along with some floor. The immediate roof is formed by the "middleman" stone parting which supports a rider seam. Both parting and rider average about 12 in. At the face ends, both rider and parting are taken to provide additional headroom. The No. 2 longwall is in its second panel, and front and side abutment loads are fully developed. As a consequence of this and other factors, the face sloughed extensively both between passes of the shearer and immediately in advance of the drums when the machine was cutting. Delays due to large lumps hanging up at the headgate transfer point were common on the cutting run, while stoppages due to slabs jamming under the shearer tended to punctuate the flit to the tailgate.

TABLE 2. - Reversed drum evaluation site description

JWR No. 2 mine No. 2 longwall	
Panel depth	2,000 ft
Panel length	600 ft
Extraction height:	
face	66 in.
face ends	96 in.
Ventilation direction	Tail-to-head
Ventilation quantity	50,000 cfm (typical)
Face cross section	60 ft^2
Roof support type	Thyssen two-leg lemniscate shield (IFS canopies)
Mining cycle	Modified half-face
Shearer type	Anderson Manor 500, DERDS
Drum:	
Diameter	62 in.
Web	32 in.
Loading vanes	2 start
Sprays	Conflow staple-lock, 1 per pick
Face conveyor	Mining supplies 2 x 26 mm inboard chain

d. Face equipment - The roof supports consist of Thyssen two-leg lemniscate "one web back" shields of conventional design. The shearer is an Anderson Manor AM 500 double ended ranging drum machine. In the context of this trial, the machine had four notable features:

1. Two drum rotation speeds were selectable at each gearhead. The "high" and "low" speeds were 39 and 27 rpm, respectively. The machine was normally operated in the low speed setting at 27 rpm. This speed is on the lower bound of current practice.

2. A form of shearer clearer was fitted to the machine. This consisted of spray bars located just outboard of each gearhead and two venturi sprays mounted on the face side of the shearer body. A passive barrier approximately 6 in. in height was mounted 9 in. from the gob side edge of the machine.

3. No cowl as fitted to the headgate drum.

4. The operators' positions at both ends of the machine coincided with the ends of the gearheads. The operators were, therefore, within 1 or 2 ft of the plane of the trailing edge of the drums.

Figure 9 shows the general layout of the face and the trailing arm of the AM 500 shearer. The drum in the lower photograph is in the reversed rotation configuration.

4.2 EVALUATION PLANNING AND EXECUTION

Two principal concerns had a major effect in determining the content of the test plan. The first of these was the requirement that the drum change be scheduled in advance to fit in with other mine activity. There was, therefore, little or no leeway if good data was not gathered in the first week (reversed condition). It was assumed that at least four good shifts of data would be available during this week and that between five and ten cycles of data could be obtained. A similar effort would then follow during the week of operation with conventional rotation. Following this week, the drums would be changed to an experimental drum with a larger pick.

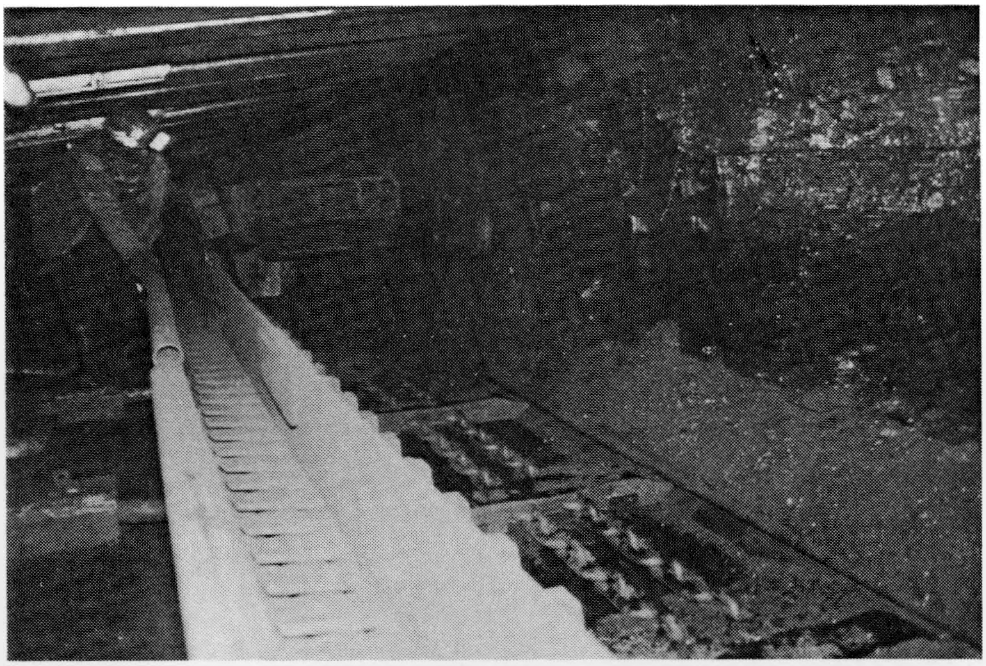
The other main concern was the need to define measurement locations and methodology that would maximize the potential for detecting dependence of dust levels on drum rotation direction. It was decided that this would best be achieved by sampling with RAM-1 instruments at three positions that would move with the shearer. These positions were:

a. Upwind of the shearer (intake position)

b. Downwind of the shearer (return position)

c. At a shearer operator's position.

The reversed drum evaluation commenced on Monday, 16 January. The plan at that time was to sample for the balance of that week in the reversed drum condition, to



a) FACE LAYOUT

b) AM 500 TRAILING DRUM (REVERSED ROTATION)

FIGURE 9. - Face equipment.

swap the drums during the weeks of 21-22 January and to gather data in the conventional rotation mode during the week beginning 23 January.

On Monday, 16 January, the face was operational, and upon the arrival of the team at the longwall, it was surveyed to allow measurement locations to be chosen. This procedure involved the measurement of shearer dust profiles to allow a suitable measurement position to be chosen at the shearer, and the taking of data at two positions on the return side of the shearer to allow the correct downwind position to be located.

The initial profile along the shearer indicated that a position approximately at the center of the machine was representative of the operator's exposure. The intake sampling location was set at 20-ft upwind of the shearer drum leading edge while the downwind location was located 30 ft from the drum edge. The upwind sampling point was approximately 9 in. above the spillplate. The choice for the downwind location was between the spillplate position and a position that was biased towards the face above the panline.

Following an initial cycle of data gathering in each position, the "above the pan" location shown in figure 10 was selected. This was because the plane of the spillplate represented the mixing zone between the dusty air from the machine and the relatively clean air that had passed around the machine in the travelling way. The decision to use the panline position was made despite some procedural difficulties that had to be overcome. These involved taking special care to ensure that the cyclone intake did not block and that the cyclone itself was not inverted accidentally when it was held out over the conveyor on an anemometer wand. When sampling began, the procedure employed was to take data at each shield from the 100th to the 20th shield. This range represented normal cutting or tramming and was not influenced by sumping or variations in ventilation at the face ends.

During the first week, valid data was obtained on each of the next 3 days (Tuesday through Thursday). On Thursday, however, it became apparent that the shearer had suffered bearing failures that required the full attention of the JWR maintenance crew during Friday and the weekend. No data was gathered on that Friday due to the failure, and the decision was made to return to Boston since JWR would not be able to swap drums during the coming weekend.

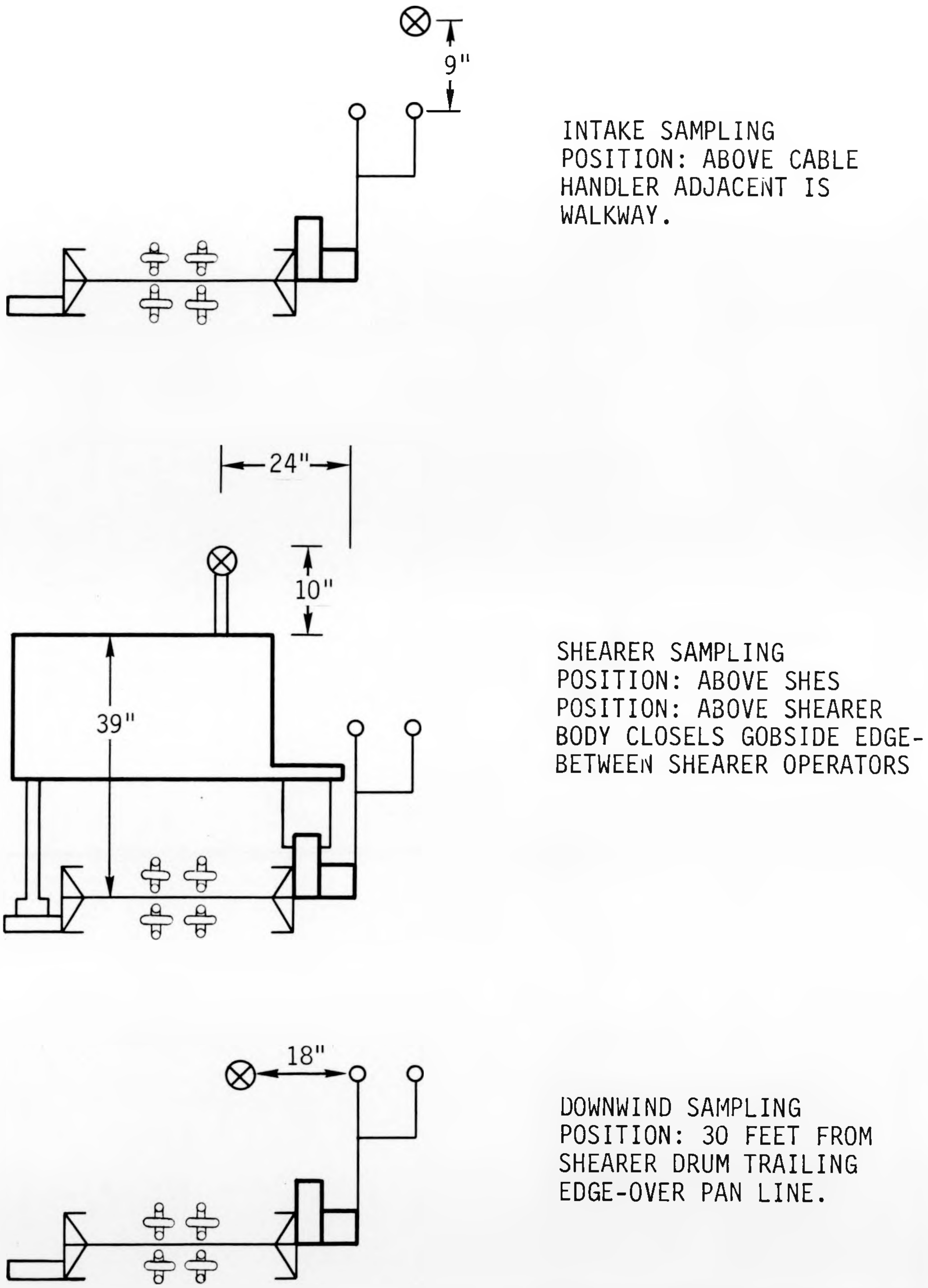


FIGURE 10. - Location of sampling positions.

Following the repair of the shearer, the drums were swapped on Saturday, 28 January, and data was taken during the subsequent week from 30 January to 3 February.

4.3 EVALUATION RESULTS AND ANALYSIS

The evaluation resulted in a data set with the following major components:

a. Shearer dust profile data taken in "floater" positions. This involves a stationary observer recording dust levels as the shearer moves by.

b. Full cycle mobile dust data sampled on a once per shield basis at three positions around the shearer by observers who moved with the shearer.

c. Gravimetric sampler data from a return crosscut.

d. Other data such as ventilation profiles and ROM coal size distribution.

The analysis and results of each type of data are discussed below.

4.3.1 Shearer Dust Profile Data

The first analysis involved the shearer dust profile data (floater data). These consisted of three and four passes in the reversed drum and conventional conditions, respectively. The profiles for each condition were superimposed and the mean value calculated for each 5-ft increment between the position approximately 35-ft downwind of the shearer headgate drum and 25-ft upwind of the tailgate drum. These average values are tabulated in table 3 and are shown graphically in figures 11 and 12. The figures also include an indication of the range of values encountered. The measurements, which were made in the vertical plane that includes the spillplate, allow a comparison to be made of the distribution of dust around the shearer.

It would appear that, while the shearer is cutting, dust levels both upwind and downwind of the machine are broadly similar in both the reversed rotation and the conventional configuration. There is a big difference, however, along the body of the machine. This is manifested over the upwind two-thirds of the machine by conventional rotation dust levels that are several times higher than those for reversed rotation. The position used for the mobile sampling was within this area. The other noticeable difference is the peak that occurs for reversed rotation just downwind of the leading drum.

TABLE 3. - Dust levels around the shearer during cutting with reversed and conventional rotation

Position	Average dust level, mg/m³	
	Reversed rotation	Conventional rotation
-40[1]	7.9	-
-35	10.8	-
-30	8.3	6.1
-25	8.6	6.3
-20	8.0	7.1
-15	6.7	6.6
-10	6.2	5.3
-5	10.7	6.5
Drum leading edge	13.5	6.9
Drum centerline	5.7	4.9
Drum trailing edge	3.5	-
Operator's position	3.9	2.9
Gearhead	1.2	2.0
Dust monitor	0.9	2.8
Haulage control	0.5	-
Gearhead	0.6	2.2
Operator's position	0.7	3.7
Drum leading edge	-	-
Drum centerline	0.7	4.4
Drum trailing edge	0.7	4.7
+5	0.4	0.7
+10	0.4	0.7
+15	0.3	0.4
+20	0.4	0.5
+25	-	-
+30	-	0.3

[1]Negative indicates downwind of the shearer, positive indicates upwind (intake side) of the shearer; the machine is cutting with ventilation.

There is less difference between the dust profiles for tramming and loading (from headgate-to-tailgate), though there is some suggestion that levels are more variable during conventional rotation.

4.3.2 Mobile Sampling Dust Data

The main data set from the mobile sampling was analyzed by taking five cycles of data representing

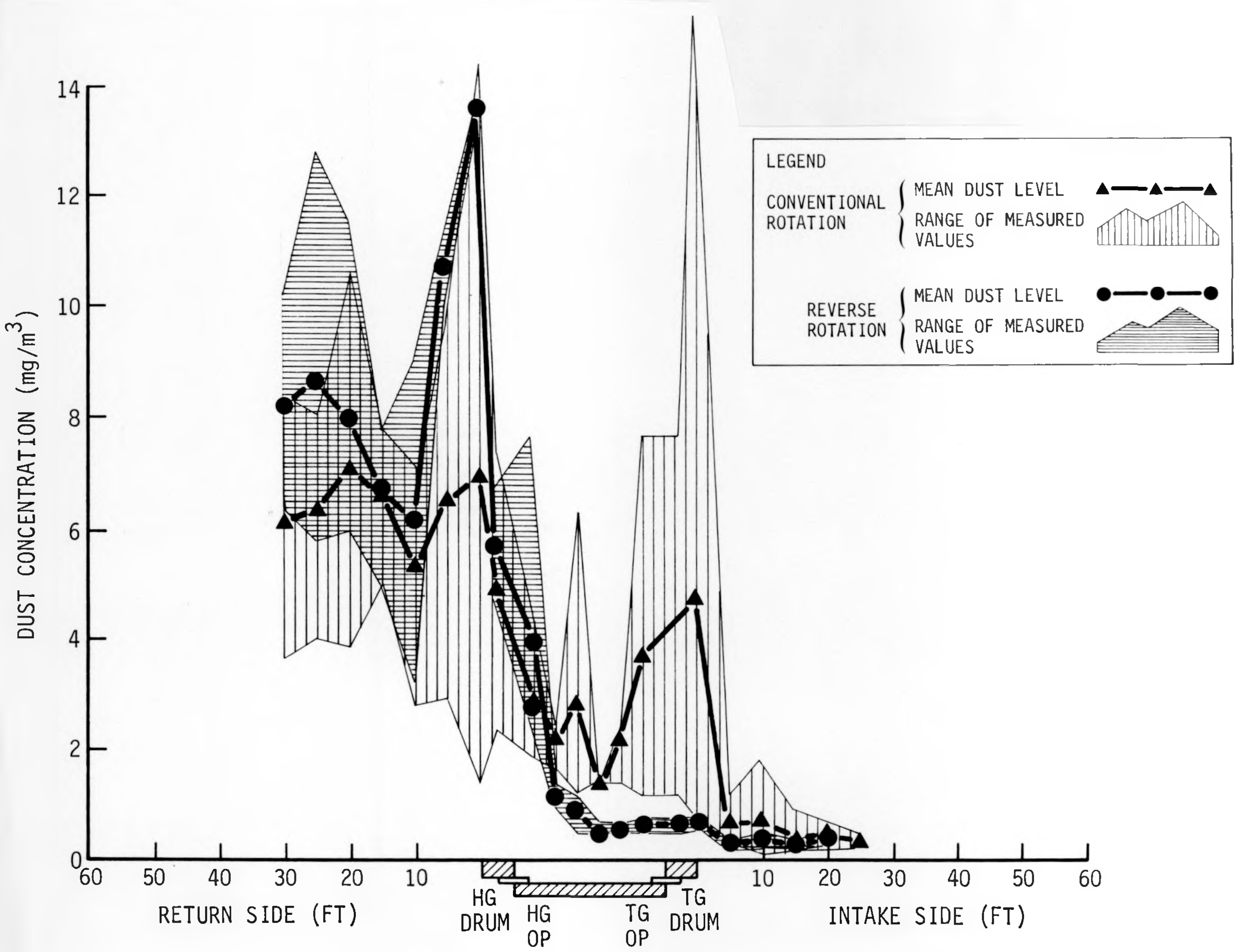


FIGURE 11. - Dust levels around the shearer (above the cable tray) during cutting from tailgate-to-headgate.

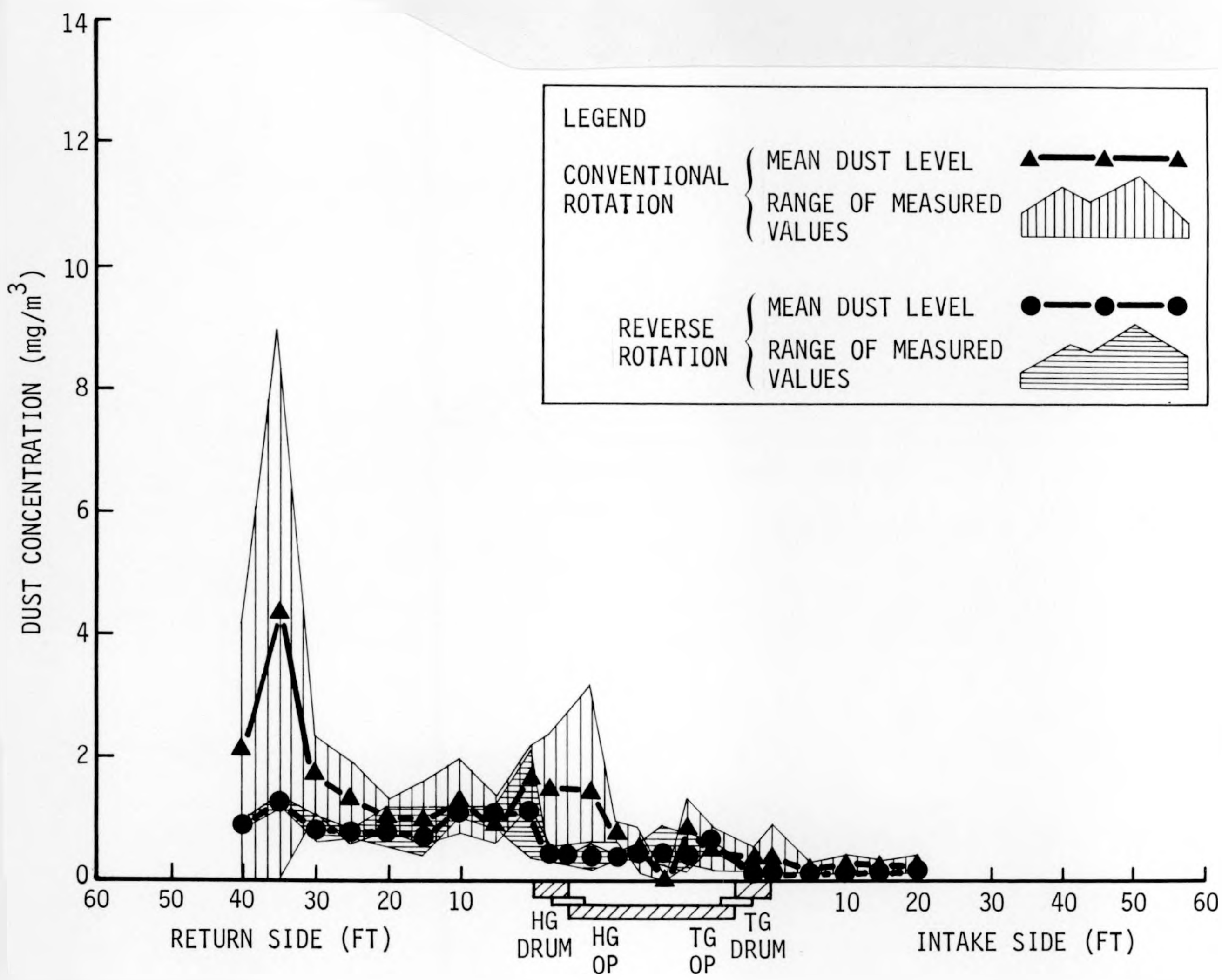


FIGURE 12. - Dust levels around the shearer (above the cable tray) during tramming from headgate-to-tailgate.

complete reversed rotation mining cycles, and six cycles representing conventional mining. These were tabulated and averaged so that "average dust levels" were available for each shield, broken down as follows:

a. For each measurement position; e.g., 30-ft downwind, at the shearer, and 20-ft upwind

b. For each direction of rotation

c. For cutting (tail-to-head) and tramming (head-to-tail).

These values were calculated for each shield between shield 20 and shield 100. The average values for each group of five shields are plotted in figures 13 through 16 which show the relationship between the dust levels measured at the three positions relative to the shearer and under the two rotation regimes and shearer travelling directions. The five shields' average value was used to produce a relatively smooth plot and to make comparison easier.

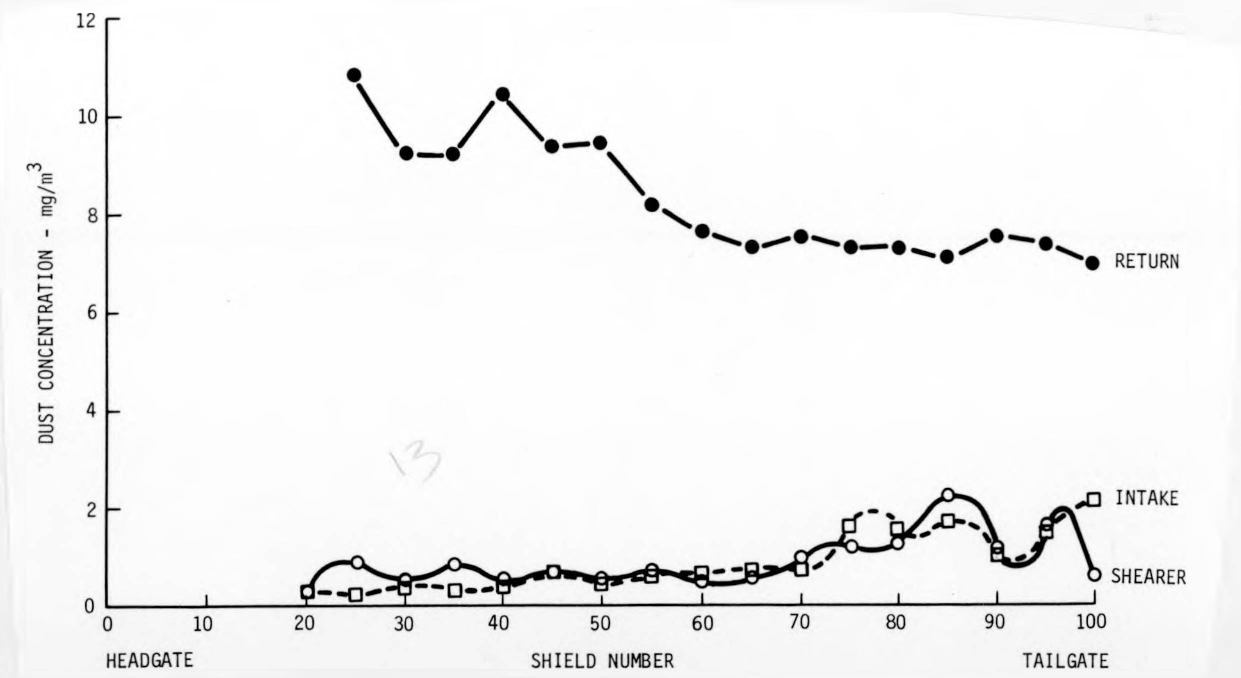


FIGURE 13. - Average dust concentrations of five tail-to-head cutting passes - reversed drum rotation.

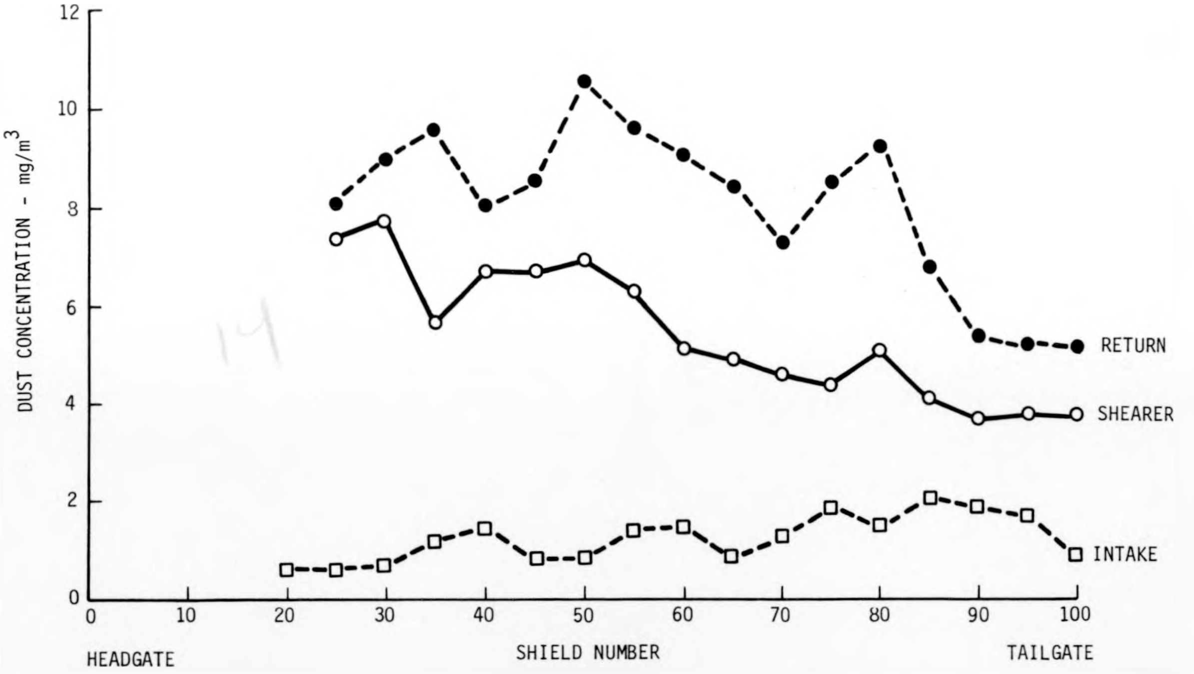


FIGURE 14. - Average dust concentrations of six tail-to-head cutting passes - conventional drum rotation.

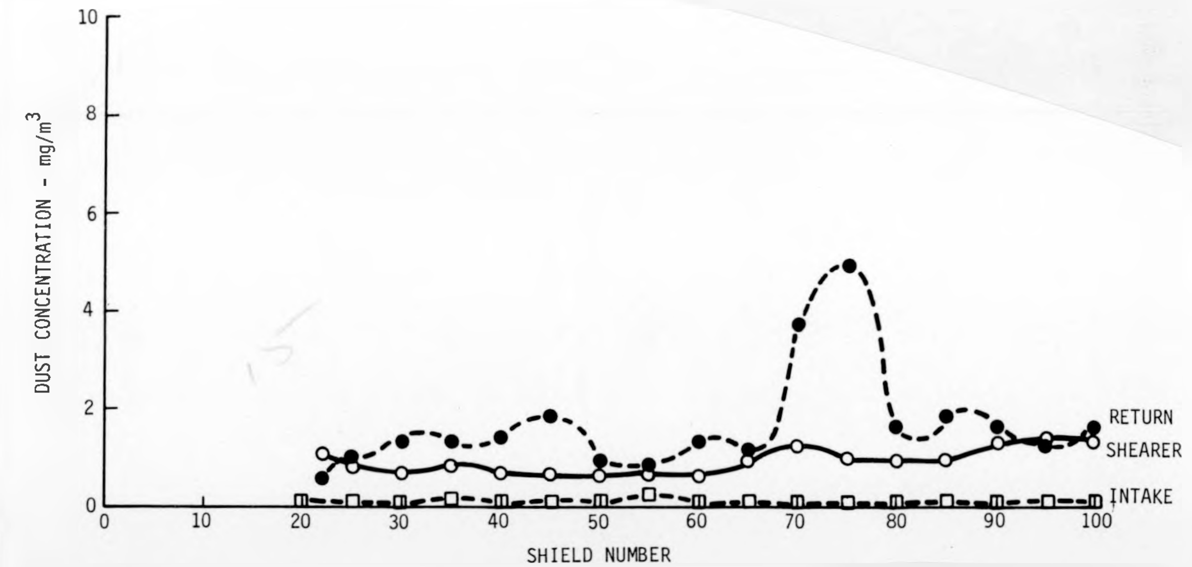


FIGURE 15. - Average dust concentrations of five head-to-tail tramming passes - reversed drum rotation.

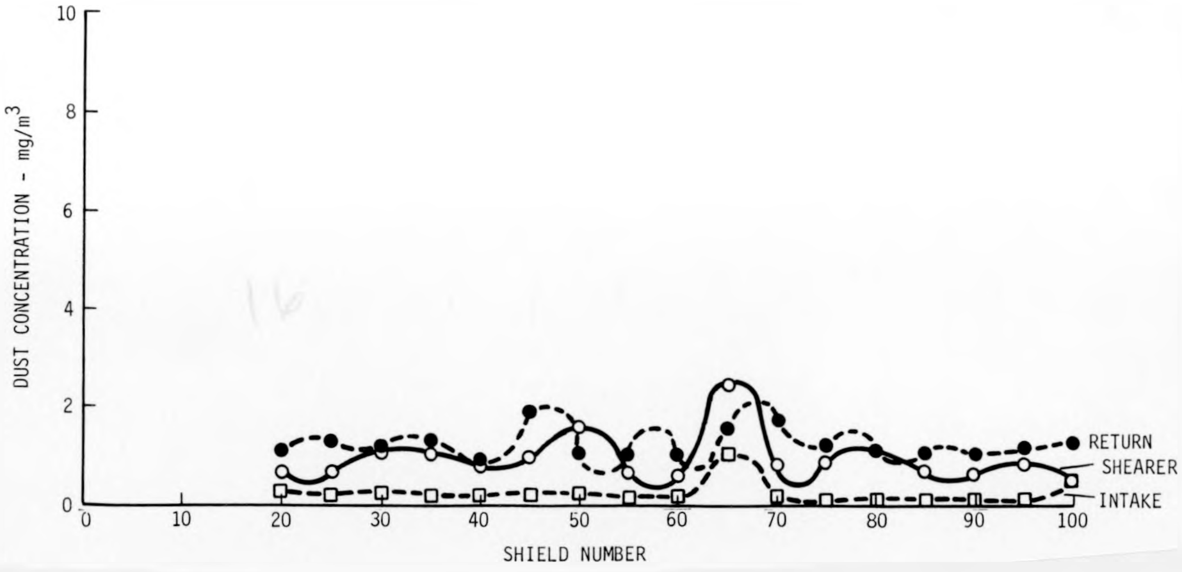


FIGURE 16. - Average dust concentrations of six head-to-tail tramming passes - conventional drum rotation.

Figures 13 and 14 allow comparison of the dust levels measured during cutting from tail-to-head. Examination of these figures leads to the following conclusions:

a. Intake dust levels on both weeks are comparable although there was slightly more intake dust during the conventional rotation week.

b. Intake dust levels tend to be higher on the tailgate half of the face. This reflects the practice of pulling every other shield in this area.

c. Conversely, the downwind dust levels in both cases tend to be higher at the headgate end of the face. This probably reflects some underlying mining condition such as abutment loading.

d. Finally, when reversed drum rotation is employed, the dust level at the shearer operator's position closely reflects the intake dust level. When conventional rotation is used, the shearer operator levels are several times higher and approach those measured downwind of the shearer.

Figure 17 shows a comparison between the shearer operator position dust levels during cutting for reversed and conventional rotation.

Figures 15 and 16 show similar dust profiles for the tramming run from headgate-to-tailgate. In both cases, intake dust levels were low and largely invariant. Dust levels measured at each sampling position were comparable under both the reversed and conventional rotation condition. The only excursion from normality is a single "hump" in the downwind face dust profile at shield 75 in the reversed drum condition.

The comparisons that were made above in terms of graphical data can also be made on a numerical basis. In order to do this, average dust levels for each cycle were calculated and the mean taken to provide an overall average dust level for each condition and measurement position.

Table 4 shows the results of this activity and provides a numerical basis for the conclusions mentioned above. For example:

a. The average intake dust levels during reversed and conventional operation were 0.8 and 1.3 mg/m^3, respectively.

b. The downwind dust levels averaged 8.5 mg/m^3 for reversed rotation and 8.1 mg/m^3 for conventional rotation.

c. The shearer position averaged 0.8 mg/m^3 for reversed rotation which is the same (after rounding) as the intake dust level.

d. In the conventional rotation mode, the same position recorded 5.5 mg/m^3. This is 68 percent of the downwind level and 412 percent of the intake level in this mode.

e. The average dust level at the shearer position during reversed rotation was 15 percent of that at the same position during conventional rotation.

The tramming to the tailgate data in table 4 does not show any consistent variation between reversed and conventional rotation.

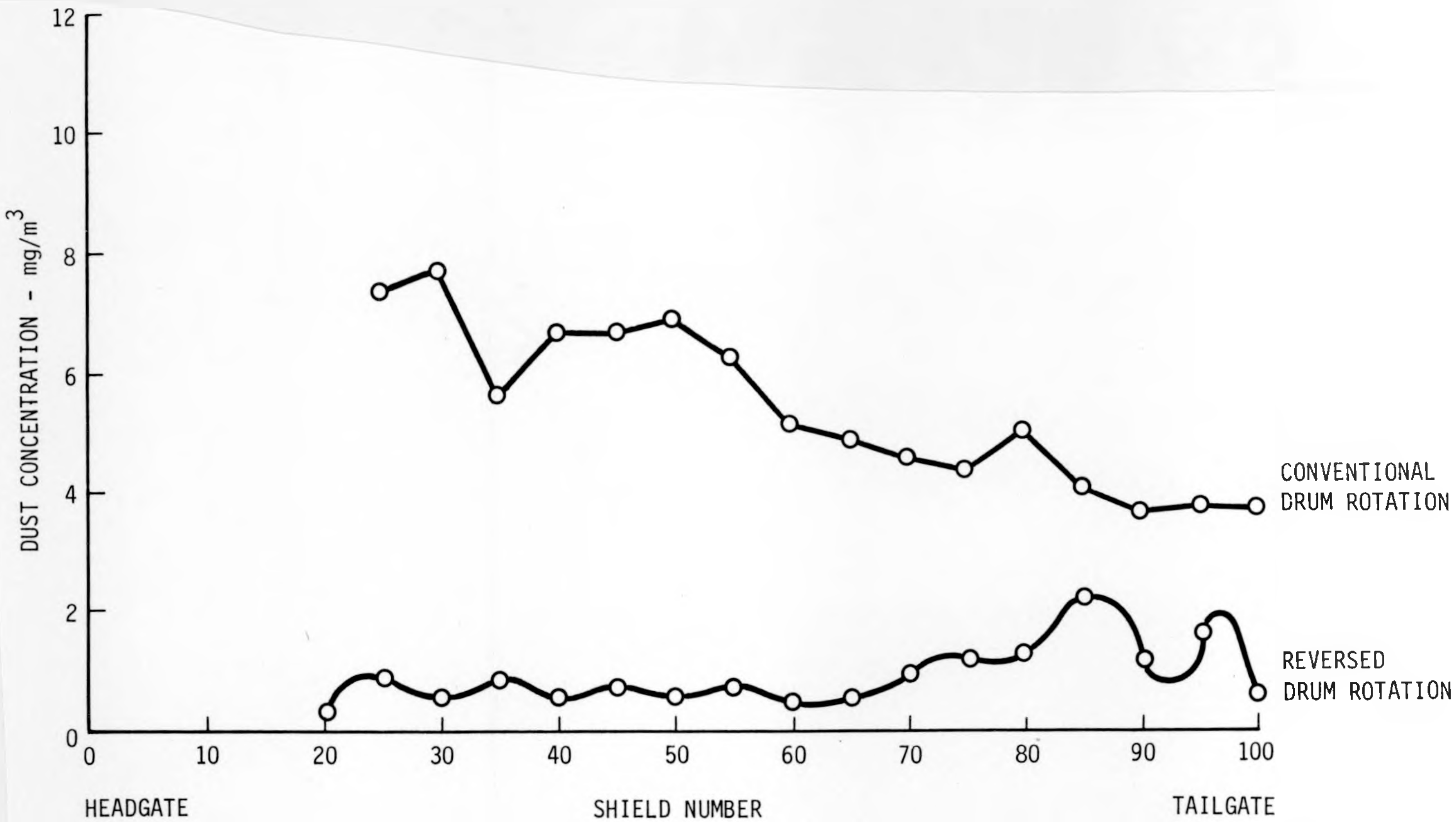


FIGURE 17. - Comparison of shearer dust levels.

TABLE 4. - Summary of average dust levels

Type of operation (cutting T to H or tramming H to T)	Measurement position	Average dust level, mg/m³	
		Reversed rotation	Conventional rotation
Cutting[1]	Return	8.53	8.05
	Intake	0.81	1.33
	Shearer	0.83	5.48
Tramming[1]	Return	1.54	1.20
	Intake	0.15	0.31
	Shearer	0.90	1.00

[1]Averages are based upon five or six passes with measurements made at each shield between the 100th and 20th shields.

4.3.3 Gravimetric Sampler and Other Data

Gravimetric samplers were positioned in the return crosscut during the 2 weeks that the evaluation was underway. The filters from the samplers were weighed and the resulting data broken down into a figure that represents milligrams of dust measured (deposited) per cutting cycle. Six samples were taken during reversed rotation and fifteen during conventional rotations. The average deposition per cycle was 1.8 and 1.3 mg, respectively. The difference between these figures was examined statistically (see appendix A) and was found to be significant in the statistical sense. It is not possible, however, to conclude that the reversed rotation produced more total dust make. This is because there were significant differences between the configurations of the return crosscuts and belt entry airflow during the period of the evaluation which could also account for the observed difference in return airway dust concentrations.

4.3.3.1 Ventilation

Ventilation measurements were made throughout the evaluation. These consisted of face airflow quantity determinations and face ventilation velocity profiles. These measurements are summarized in appendix B.

4.3.3.2 Coal Samples

A sample of ROM coal was obtained by JWR personnel during both the conventional and reversed drum operations. These were subjected to the standard particle size analysis. Figure 18 shows the cumulative size distribution plotted against screen size, while figure 19 shows the percentage of each sample that fell within each size range.

In examining this data, one should bear in mind that a single sample only was taken in each condition, and that any difference between samples could be attributed to a cause other than the direction of drum rotation direction. With this in mind, it can be observed that the reversed rotation sample contained significantly less fine coal than the conventional rotation sample. This was true of all size ranges that are smaller than 1-1/2 in. When the relative proportions of the very small size range (<200 and 200 to 100) are examined, it is notable that the conventional rotation produced between one-quarter and one-third more fines than reversed rotation.

At the other end of the size range, the reversed rotation sample contained significantly more coal in the 1-1/2 to 4-in. size range.

4.3.3.3 Photographs

The photographs shown in figure 20 are an attempt to substantiate the statement that coal loading from the trailing drum was superior when reversed rotation was employed. Figure 20(a) shows the pile of coal produced by the shearer when it continued cutting with reversed rotation during a period when AFC was stopped. The figure shows a coal pile that was loaded in an orderly manner through the lower part of the gap between the cowl and the ranging arm. Figure 20(b) is an attempt to show the loading action of a conventionally rotating trailing drum. In the original photograph at least, a large quantity of coal can be seen being thrown over the ranging arm and onto the AFC.

4.4 REVERSED DRUM EVALUATION CONCLUSIONS

The use of reversed drum rotation on the No. 2 longwall at JWR No. 4 mine resulted in a significant reduction in dust levels during cutting with the ventilation in the areas occupied by the shearer operations.

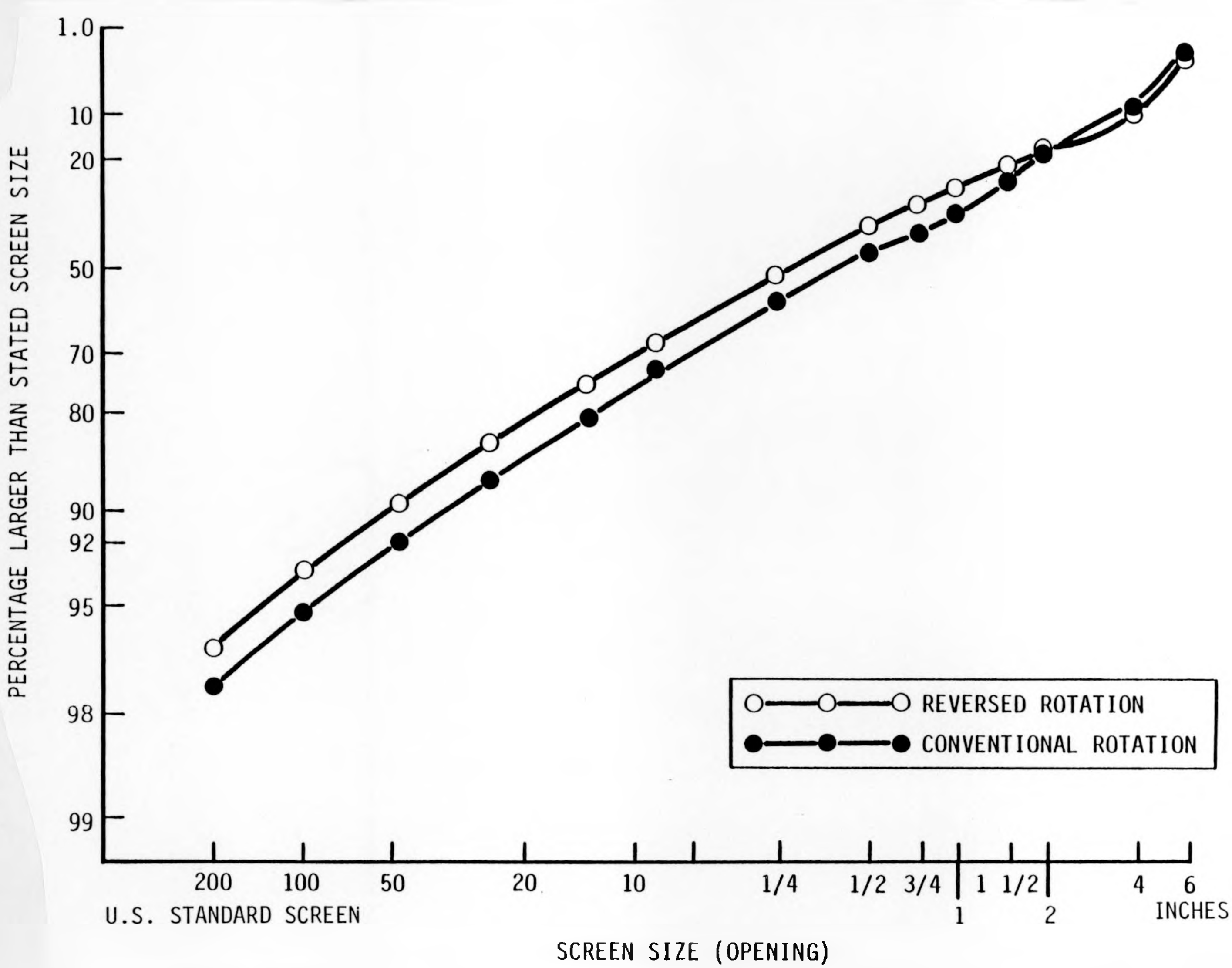


FIGURE 18. - Cumulative size distribution of coal samples.

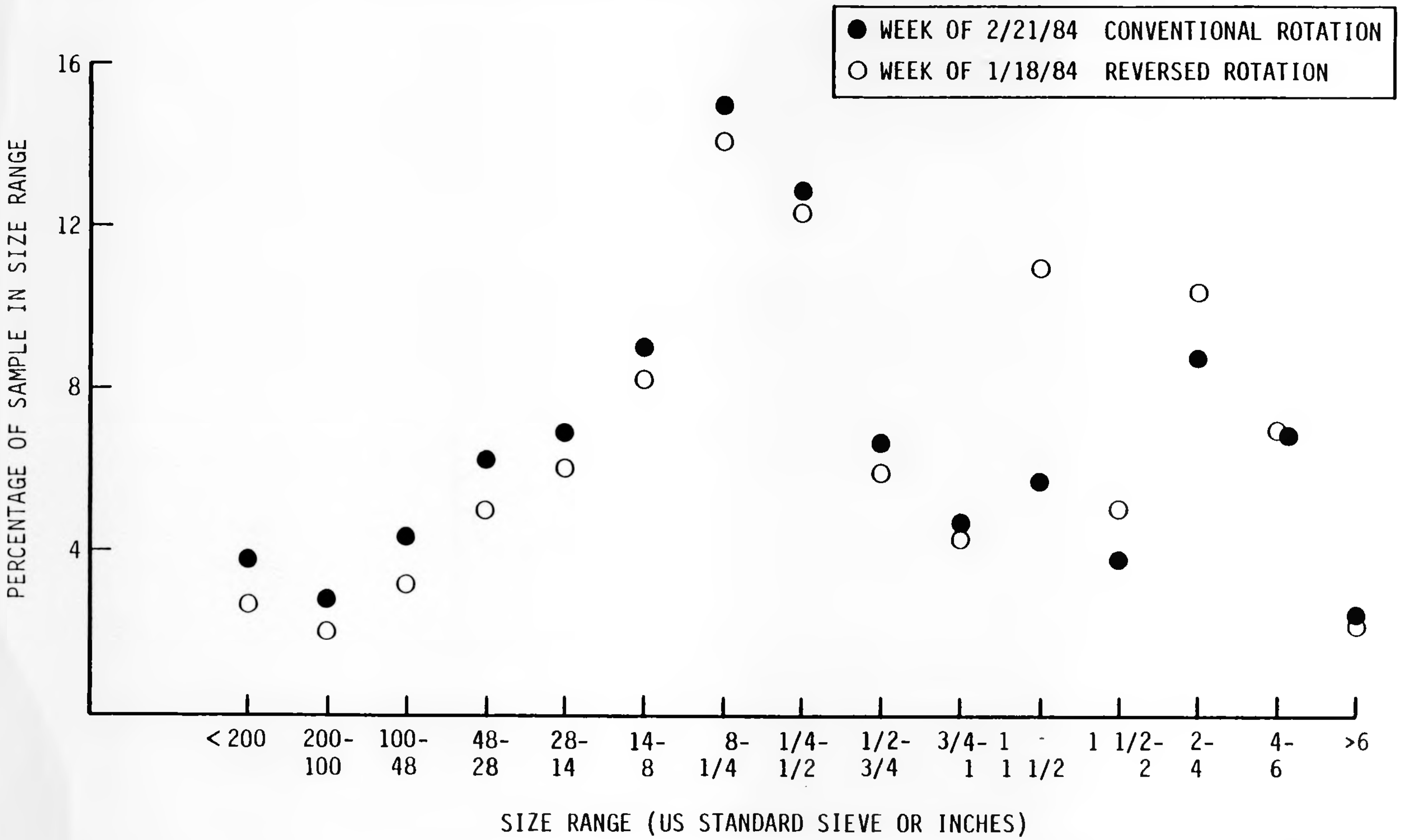
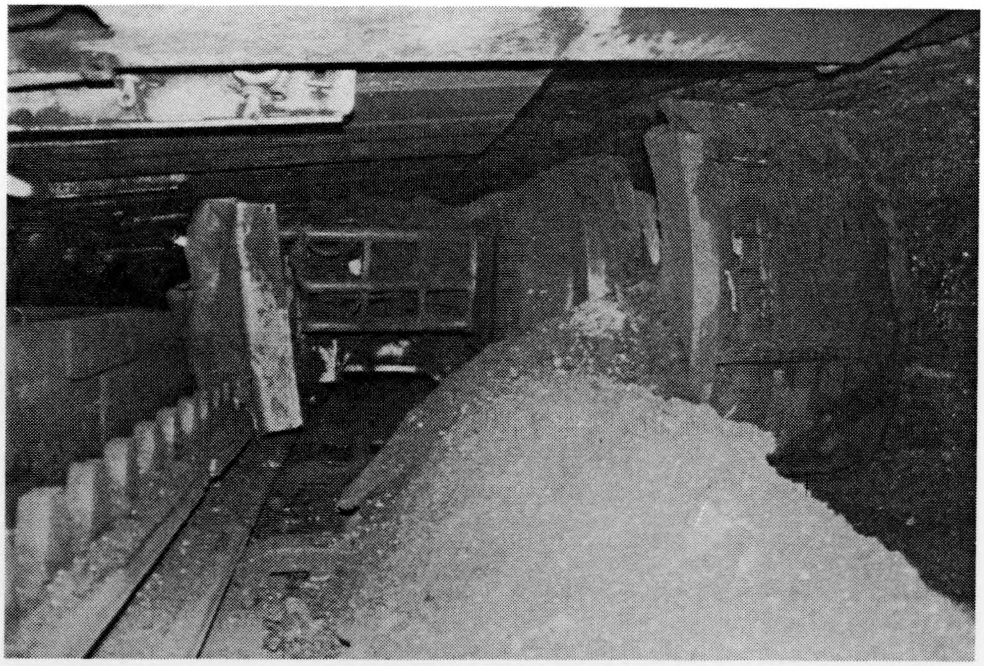


FIGURE 19. - Distribution of coal sample sizes.



a) REVERSED ROTATION LOADING

b) CONVENTIONAL ROTATION LOADING

FIGURE 20. Coal loading.

This conclusion is supported by both the dust profile data (table 3) and the full pass data (table 4). It is also strongly evident in terms of observations of visible dust and loading action and is supported by comments made by the shearer operators.

At this site, the reduction of dust level produced by drum reversal (at the point halfway between the operators' positions) was in the ratio of 6:1. The average dust levels were 5.48 and 0.83 mg/m^3 for conventional and reversed rotation, respectively. This degree of reduction was determined by the ratio of conventional rotation shearer dust make to intake dust levels since there was little or no evidence of shearer-generated dust at this position in the reversed drum mode.

There was no evidence that the dust levels downwind (on the return side) of the shearer were different in the reversed rotation or conventional modes. Similarly, the direction of rotation did not have any significant effect on dust levels during tramming from head-to-tailgate.

The use of reversed rotation did have a slight negative impact on the operation of this particular face. This was due to the relatively inefficient way in which a reversed rotating drum loads rocky lumps or slabs. This problem can be viewed in terms of the varying results which occur when the drum meets a lump of strong material. In the conventional rotation case, the leading drum vane picks are descending and will trap and probably cut (or break) the lump against the AFC or floor. A reversed rotating (floor-to-roof) leading drum will introduce picks <u>under</u> the lump and may move it and load it onto the AFC without breaking it.

On the JWR's face, it was observed that stoppages to clear blockages at the AFC/stageloader transfer point occurred more frequently during reversed rotation. This problem was, to an extent, due to the temporary absence of a lump breaker from this position. It is noteworthy that the mine management did not consider this increase of short stoppages to be too high a price to pay for the other benefits of reversed rotation.

In addition to the reduced operator dust levels, these benefits include a better size range of ROM product from reversed drum cutting. The mine operator reported that the reversed mode reduces the proportion of fines in the product, and that the preparation plant throughput, which is governed by fines handling capacity, was greatly improved when reversed rotation was used. This was one of the reasons why the mine normally used reversed rotation on this face. Though the single pair of coal size samples taken cannot be regarded as conclusive evidence, it seems that reversed rotation does produce a ROM product with fewer fines.

The hypothesis that this reduction in fines results from improved loading cannot be proved in the formal sense. The supposition that improved loading conditions in the trailing drum are the cause of the reduced dust levels must also remain "not proven." However, these cautions concerning cause and effect should not obscure the fact that the results of this evaluation provide documented evidence of a significant reduction of operator dust levels that occurred when reversed rotation was used during cutting with ventilation. While there can be no guarantee that the results obtained on one coal face will be repeated on another, there is strong circumstantial evidence that a large part of the reduction in dust level was a result of the improved loading ability of the trailing drum. Unfortunately, there is another factor which may have had some influence on loading from the trailing drum on this face. This complicating factor is the variation of the amount of coal left unloaded by the leading drum which was not fitted with a cowl. In this condition, it is reasonable to expect that a conventionally rotating leading drum would leave more coal on the bench to be loaded by the trailing drum. The poorer loading conditions in the trailing drum during conventional rotation, might, therefore, have been exacerbated by having to handle a higher volume of coal.

Even allowing for this factor, this evaluation has presented strong empirical evidence for the thesis that states that when loading from an upwind trailing drum is improved, a substantial reduction in airborne dust will result. This improvement can be produced by adopting reversed drum rotation. The extent of the reduction compared to conventional rotation will depend upon drum design, mining conditions and cowl layout.

Following the evaluation, JWR again reconfigured their No. 2 longwall to reversed drum operation and once again enjoyed the benefit of improved loading, lower dust levels at the shearer, and a more easily washed product with fewer fines. Other longwall operators should be encouraged to actively consider this low-cost dust control option. Potential users should consider several factors, however, to ensure suitability of their machinery and conditions to reversed drum rotation, these are discussed below.

4.4.1 Mechanical Feasibility

The underlying assumption is that, switching drum from one end of the machine to the other and reversal of the direction of rotation of the shearer drum hubs, will result in the correct setup for improved loading.

The changing of shearer drums is a task that is familiar to longwall crews and which can usually be accomplished in one or two shifts. The principal factors that will determine the ease with which this change is made will be the seam height and clearance in the headgate area.

The reversal of drum shaft rotation can be accomplished by changing the relative phase of two of the three electrical supply leads to the shearer motor. If the machine is of conventional design (with a single motor), this may be conveniently done at the shearer control box or breaker box in the headgate. One of the potential complications in this case is the fact that all accessories driven off the main drive shaft such as the haulage pump and the hydraulic pump will be driven in reverse. The consequence for a haulage system will merely be that the forward and reverse lever directions will be reversed. Depending on its design, the supply and return of the shearer hydraulic services pump may have to be reversed.

If the machine is of the type that has separate motors for each function, (hydraulics, haulage, drum drive, etc.), the situation is simplified since only drum drive motors need be reversed. It should be noted that if a second set of drums exists, a trial may be conducted in which the drums are individually "reviewed" and data gathered with either headgate or tailgate drum rotating in reverse.

4.4.2 Mining Environment

The mining environment in which reverse drum rotation is contemplated should be selected so that mining conditions do not handicap the technique. In particular, the following points should be addressed:

a. The cutting cycle employed should use both drums simultaneously. A system where a single drum cuts the full extraction will not be appropriate; nor will one in which no coal is cut by the trailing drum.

b. Ideally, the trailing drum will extract a bench of depth equal to between one-quarter and one-half of the drum's diameter.

c. The drums should be adequately sized for the operating conditions in which they work. For instance, drums that are usually choked due to inadequate vane depth in a low seam will not be representative of the general condition.

d. Current drum speed should be in a range that represents good modern practice. If excessive drum speed is used, dust from cutting may overwhelm other sources. Also, projection of coal into the walkway and dust liberation during reversed drum cutting will be excessive. An ideal situation would be a machine currently operating at a relatively low drum speed with a two-speed gearbox.

e. Ventilation velocities and quantities should be within the range normally encountered. If excessive ventilation velocity is present, dust from transfer points and shield dust may make changes in dust for the shearer difficult to detect.

APPENDIX A--STATICAL ANALYSIS OF GRAVIMETRIC SAMPLER DATA

The mean (M) sample standard deviation (S) and the sample variances (S^2) of the gravimetric sampler data were as follows:

1. Reversed drum

$M_r = 1.81\ mg/m^3$

$S_r = 0.45$

$S_r^2 = 0.20$

Number of samples $n_r = 6$

2. Conventional drum

$M_c = 1.27\ mg/m^3$

$S_c = 0.3$

$S_c^2 = 0.08$

Number of samples $n_c = 15$

The "student's" t statistic is defined as:

$$t = \frac{M_r - M_c}{\sqrt{n_r \cdot S_r^2 + n_c \cdot S_c^2}} \sqrt{\frac{n_r \cdot n_c(n_r + n_c - 2)}{n_r + n_c}}$$

$$= \frac{1.81 - 1.27}{2.415} \times \sqrt{\frac{90 \times 19}{21}}$$

$$= \frac{0.54}{1.55} \times 9.02 = 3.14$$

for 19 degrees of freedom $t_{0.01} = 2.861$ and $t_{0.001} = 3.833$. The probability that the observed difference in the means of the dust levels ($M_r - M_c$) occurred by chance is between 0.01 and 0.001.

APPENDIX B--VENTILATION DATA

TABLE B-1. - Ventilation quantities, JWR No. 4 mine, No. 2 longwall

Date	Face airflow quantity, cfm	Return airflow (measured in last open crosscut), cfm
01-16-84	38,100	--
01-17-84	41,400	34,900
01-18-84	41,400	60,100
01-19-84	53,000	36,400
01-30-84	38,600	49,100
01-31-84	--	62,500
02-01-84	35,600	44,400
02-02-84	47,200	--
02-03-84	45,400	--

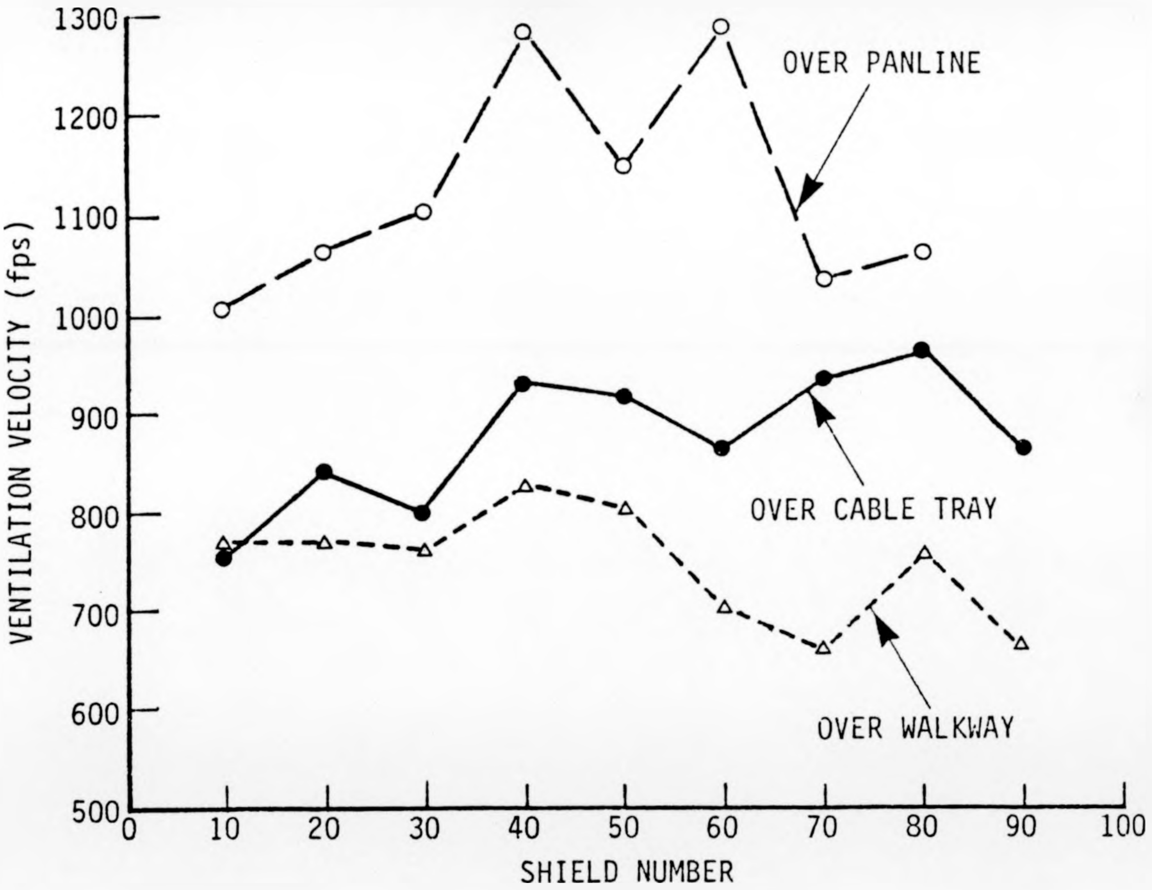


FIGURE B-1. - Face ventilation profile (average of three sets of data).